Inverted Coaxial HPGe Segmented Point Contact Detector

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Novel detector technology for in beam gamma-ray spectroscopy

The Inverted Coaxial HPGe Segmented Point Contact detector combines a coaxial geometry with a small read-out electrode (point contact) embedded in the rear of the detector. In total, its surface is covered by 20 individual electrodes, referred to as segments (see Fig. 1). The exact location of interaction sites can be resolved from the signals measured on these segments.

As the detector is intended for in beam experiments it is constructed from n-type material to increase its resistance to radiation damage. The development of n-type detector technologies in the past has been governed by the paradigm of reducing the typical path of charge carriers to the shortest possible distance. This detector breaks with this ideology by allowing large variations in the charge carrier drift time. The drift time is then used to narrow down the location of the gamma-ray interactions (see Fig. 2).

Theoretically, this detector has been predicted to be powerful for in beam gamma-ray tracking array experiments[a]. Within the scope of an ongoing LDRD project a prototype detector (see Fig. 3) is being characterized to learn about its performance in practice.

[a] A novel HPGe detector for gamma-ray tracking and imaging. R.J. Cooper, D.C. Radford, P.A. Hausladen, K. Lagergren. Nucl. Instr. and Meth. A 665 (2011) 25-32

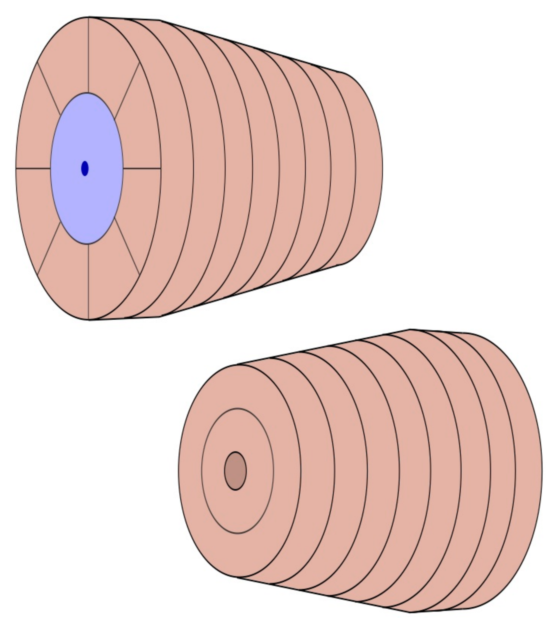

Fig. 1: A sketch of the segment arrangement: The dark blue dot indicates the point contact, the surrounding light blue area is not covered by an electrode.

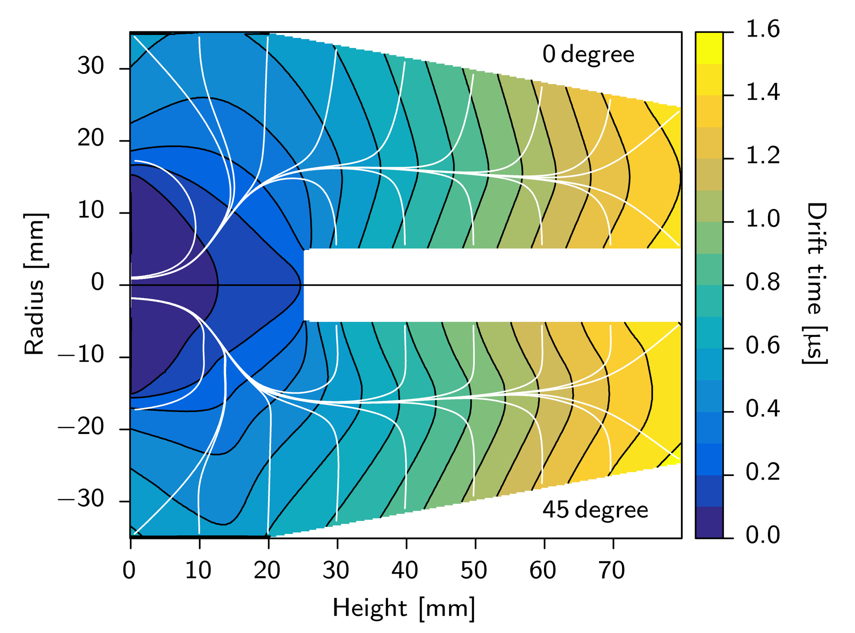

Fig. 2: The trajectories of the electrons join and follow a similar path to the point contact (white). The drift time therefore is a good proxy for the longitudinal position of the interaction (colors).

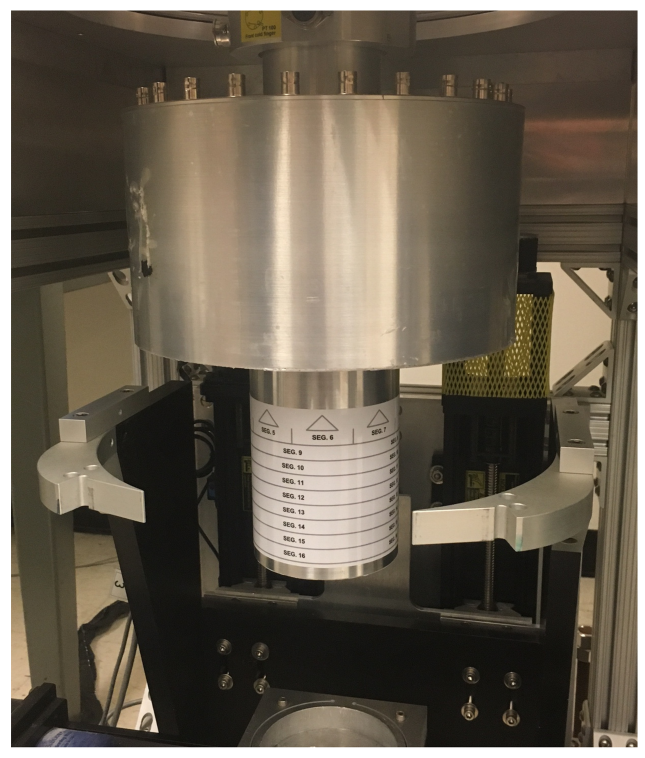

Fig. 3: A picture of the cryostat, which houses the detector. The cylinder attached to the cryostat contains the electronics.

Separation of interaction patterns

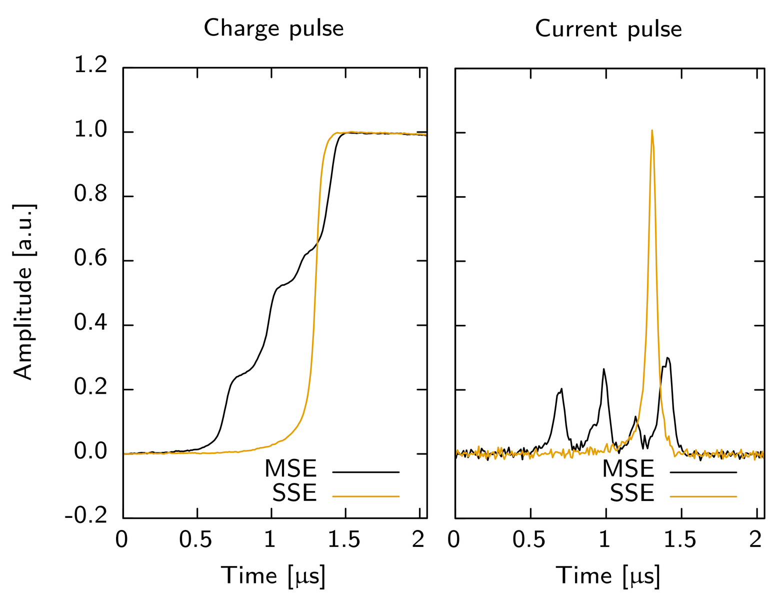

Fig. 4: The pulse shape of an event with a single interaction (SSE) is very different from the pulse shape of an event with multiple interaction sites (MSE).

High energy gamma-rays usually Compton scatter multiple times, each time depositing only a fraction of the total energy. The pulse shape that is measured at the point contact is thus a superposition of the signals produced by the individual interactions. As represented in Fig. 4, the shape of the measured signal for events with multiple interactions differs greatly from events with only a single interaction site. Moreover, the numbers of interactions can be extracted from the pulse shape.

Events with multiple interactions are much more complex to deal with. Thus, in a first attempt only events that are single site like have been considered. Later on, the algorithm will be extended to also incorporate more complex distributions of interactions.

Computation of the azimuthal angle

The signals measured on the eight segments surrounding the point contact (see Fig. 1) contain information about the azimuthal angle at which an event took place. Highly collimated ^{137}Cs measurements at a radius of 24 mm with 2.5 degree increments were used to reconstruct the typical pulse shape (averaged signal) observed on these segments at a given azimuth. These averaged signals then are compared on an event to event basis to the measured signal to find the best matching angle.

Fig. 5 shows that this algorithm indeed is capable of finding a good approximation for the azimuth of a given event.

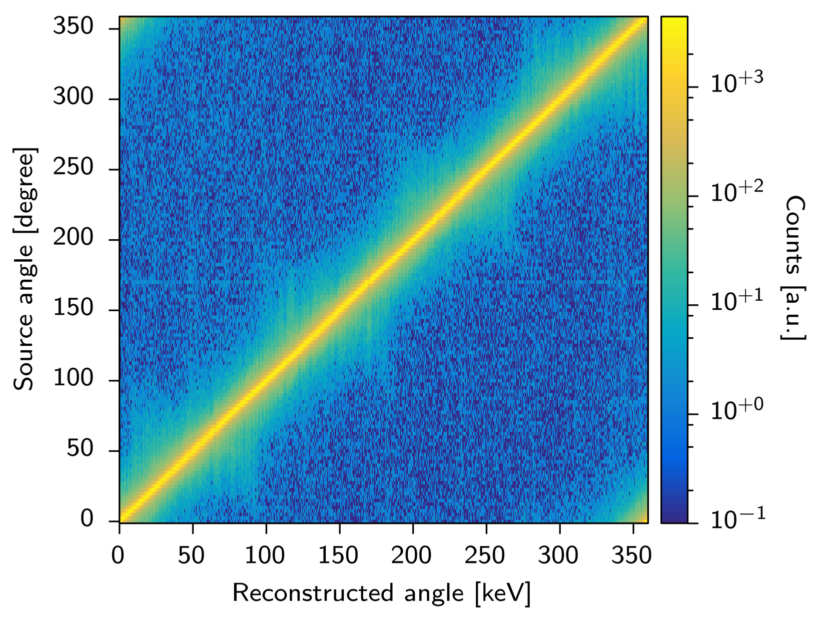

Fig. 5: The events in the 661.7 keV peak of ^{137}Cs are reconstructed at azimuth of the 1 mm collimated source.

Charge trapping correction

A fraction of the charge carriers get trapped during the drift from the interaction site to the electrode. These charges will not add to the signal that is measured on the electrode and the actual deposited energy is underestimated. Charge trapping in the Inverted Coaxial HPGe Segmented Point Contact detector depends on two main parameters: the duration of the charge collection process and the azimuth at which the charges are collected (see Fig. 6 and Fig. 8).

The location of the 661.7 keV peak as a function of these two parameters is extracted from highly collimated ^{137}Cs measurements at a radius of 24 mm and 2.5 degree increments. Thus, the energy deficiency can be characterized and an energy correction factor determined (see Fig. 7).

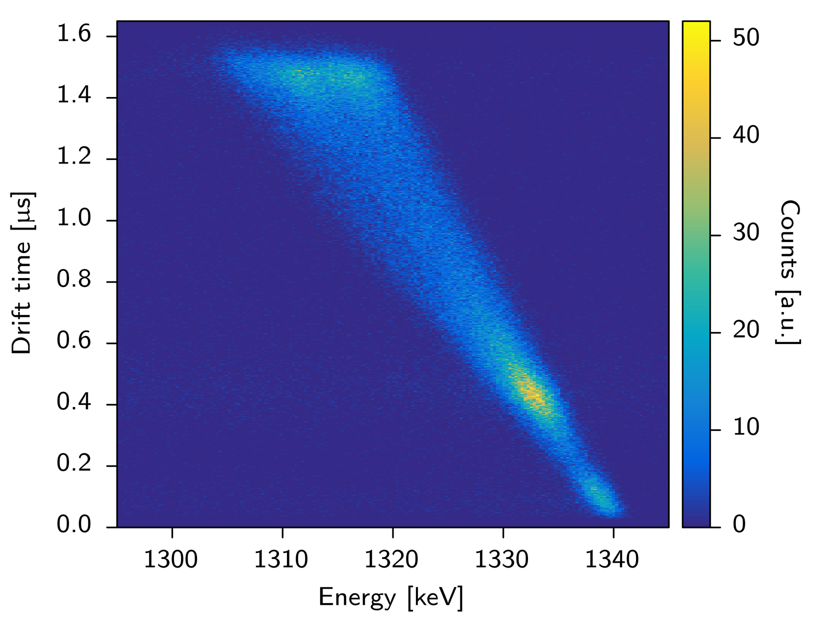

Fig. 6: Due to trapping the peak at 1332.5 keV of an uncollimated ^{60}Co measurement is reduced in energy at long drift times.

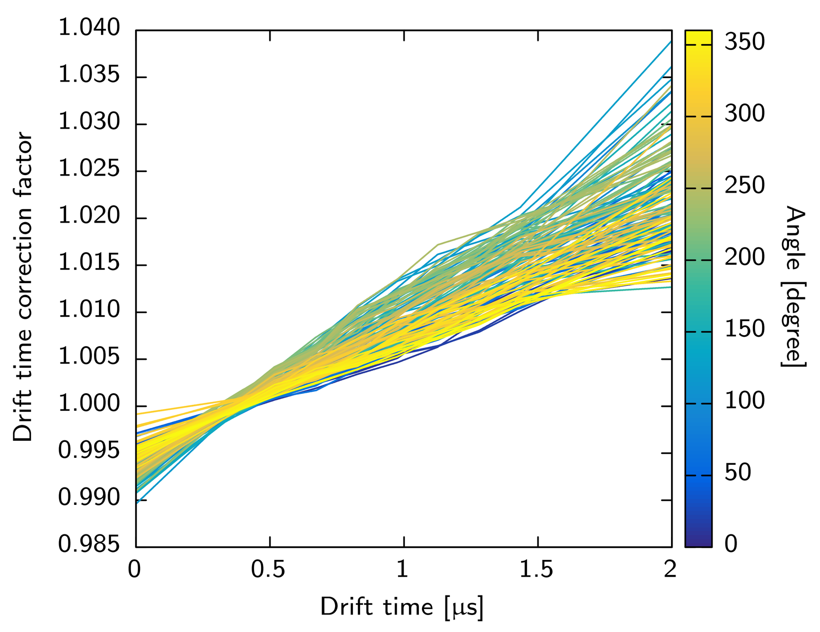

Fig. 7: The energy correction factor depends on both, the azimuth (color) and the drift time (slope).

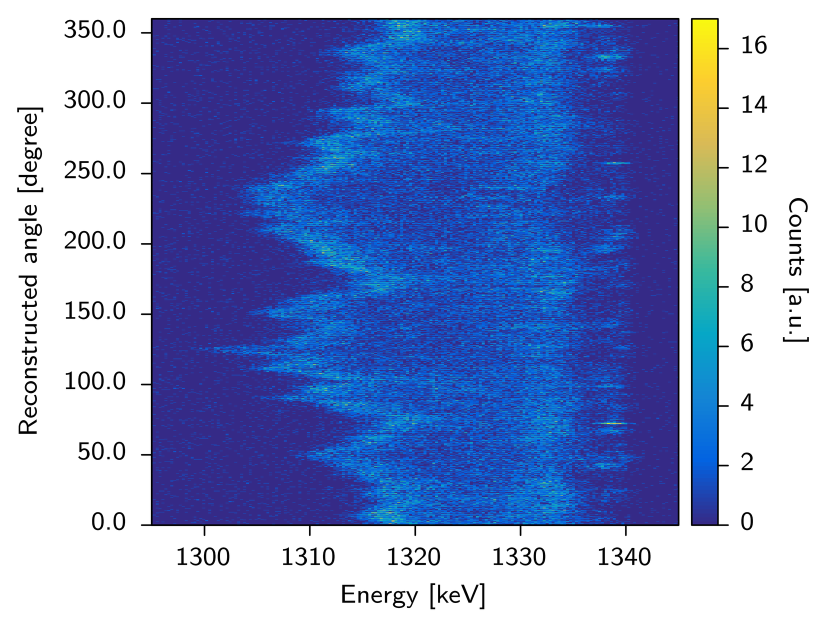

Fig. 8: Trapping affects the charge carrier differently at certain angles (for example the 1332.5 keV peak of an uncollimated ^{60}Co source).

Energy reconstruction

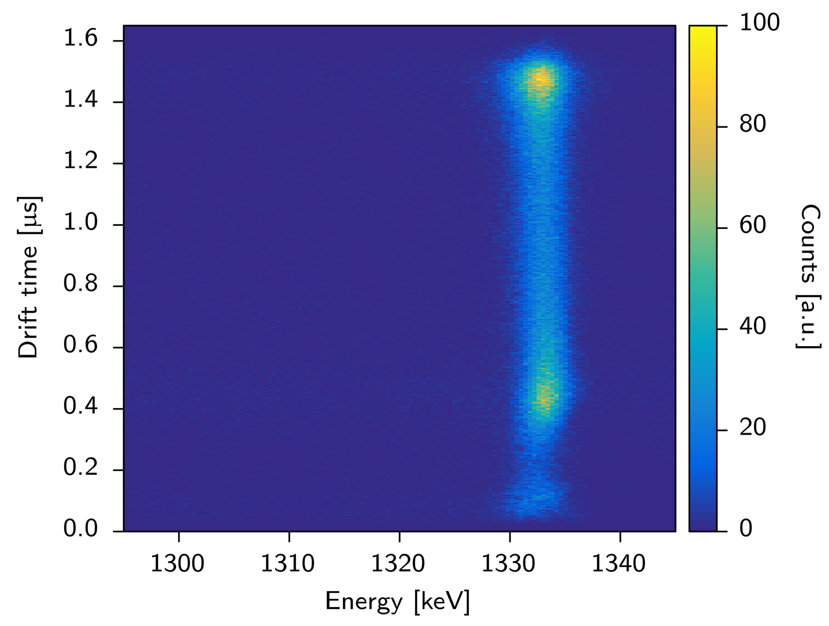

Fig. 9: With the energy correction the peak at 1332.5 keV of an uncollimated ^{60}Co measurement is located at a roughly constant location.

Fig. 11 shows that the peak shape is strongly distorted without any correction of the energy. The peak shape can be improved by simply correcting the energy by the events drift time, however, a large low energy tail remains. This tail can only be removed by also implementing a correction that is based on the angle of each event.

With all these corrections, a resolution of 3.4 keV at 1332.5 keV was obtained with a uncollimated ^{60}Co source for events with a single interaction site. Fig. 9 and Fig. 10 illustrate, that the peak now is reconstructed at a constant location and of constant width.

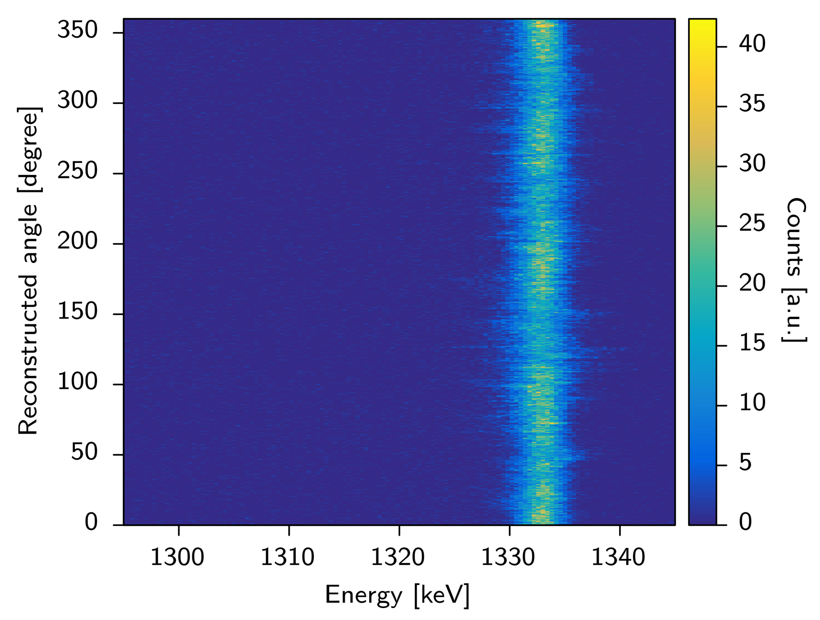

Fig. 10: Only a weak angular dependence is observed for the 1332.5 keV peak of an uncollimated ^{60}Co source after applying the energy correction factor.

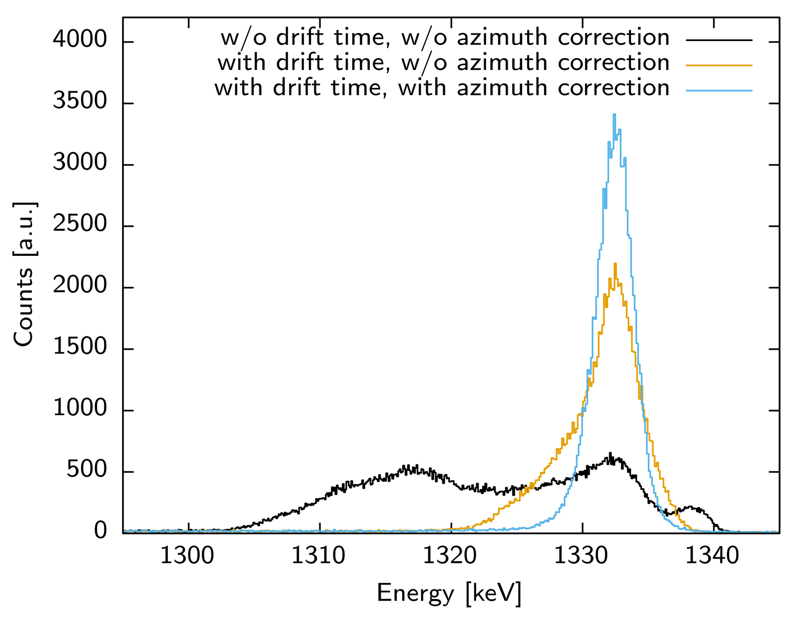

Fig. 11: The 1332.5 keV peak shape and width of an uncollimated ^{60}Co measurement improves considerably when the energy is corrected.

Summary

A first characterization of the Inverted Coaxial HPGe Segmented Point Contact detector has been performed. In particular it was observed that:

- the point contact signal allows to extract the number of interactions.
- the azimuth of single site event can be reconstructed.
- a measurement of the angular and longitudinal charge trapping strength is possible.
- a large improvement in energy resolution was achieved by correcting trapping effects as a function of the drift time and azimuth.

Further steps

Some crucial questions will be addressed next:

- Is it possible to fully reconstruct the interaction location of an event (disentangle radial/longitudinal position)? What is the highest precision that can be achieved?
- How to we apply this method to more complex distributions of interactions (multiple site events)?

Acknowledgments

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